Bi-aspheric ablation profile for presbyopic hyperopic corneal treatments using AMARIS with PresbyMAX module: Multicentric Study in Spain

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ABSTRACT: This article describes corneal bi-aspheric ablation profiles to treat presbyopia in hyperopic patients. The ablation profile is the PresbyMAX module of the CAM software. The outcomes presented here are for a series of consecutive presbyopic patients treated with LASIK between January 1, 2010 and December 31, 2010 at 4 sites in Spain. All treatments were performed as bilateral simultaneous LASIK. The results using the PresbyMAX showed that it was a well tolerated, safe and effective procedure for the treatment of presbyopia in hyperopia up to +4D.

PURPOSE: To analyse simultaneous vision (distance and near) 6-month after bi-aspheric multifocal central presbyLASIK treatments for hyperopia with or without astigmatism, based on the creation of a central area for near vision and leaving the midperipheral cornea for far vision in hyperopic patients.

SETTING: 50 eyes of 25 patients treated with the PresbyMAX technique by Dr. Iribarne, Dr. Juárez, Dr. Orbegozo, and Dr. Saiz at 4 private practices in Spain.

METHODS: Patients have been treated for correcting distance ametropiae and alleviating presbyopic symptoms simultaneously. All patients have been treated in Presby Aspheric mode. No eye had previous corneal refractive surgery. Preoperative corneal curvature ranged between 40 D and 48 D, with pachymetry thicker than 500 μm. Preoperative distance best corrected visual acuity (CDVA) was 0.1 logMAR or better, with best corrected near vision (CNVA) of 0.2 logRAD or better. All eyes were assessed up to 6 months postoperatively.

RESULTS: 25 patients treated using PresbyMAX software were reviewed. For 22 patients, 6-month follow-up was completed. At 6 months, 80% of patients achieved UDVA 0.1 logMAR or better, 91% patients obtained UNVA 0.1 logRAD or better, and 96% of eyes were within 0.75 diopters (D) of defocus. Postoperative mean spherical equivalent refraction was –0.08±0.34 D. Stability was achieved from the 3-months follow-up. 95% of patients achieved UDVA 0.2 logMAR or better AND UNVA 0.2 logRAD or better. No statistical differences between males/females were found. The mean binocular distance uncorrected visual acuity (UDVA) improved from 0.50±0.13 logMAR to 0.09±0.08 logMAR. The mean binocular near uncorrected visual acuity (UNVA) increased from 0.71±0.10 logRAD to 0.08±0.07 logRAD.

CONCLUSIONS: Patient selection and expectation management is essential to achieve patient satisfaction. Even though optically the results are predictable and good, some patients find it difficult to adapt to the compromise, others are dissatisfied by the minor loss of distance VA. In presbyopic patients without symptomatic cataracts, but refractive errors, PresbyMAX® will decrease the presbyopic symptoms and correct far distance refraction in the same treatment offering spectacle free vision in daily life in most of the treated patients. Further investigation is necessary to evaluate the overall benefit of this procedure.

KEYWORDS: aspheric, ablation, presbyopia, hyperopia, LASIK.

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INTRODUCTION

There has recently been a tremendous increase in interest of surgical presbyopic correction. The effective treatment of presbyopia combined with any refractive error has proven to be a significant challenge for refractive surgeons. Refractive corrections for presbyopia by means of excimer laser systems are as old as laser refractive surgery itself. Moreira et al said in 1993: «After multifocal ablations, a greater spread of surface powers is observed, often with a bimodal distribution, indicative of an apparent multifocal effect. These observations suggest that in some patients undergoing photorefractive keratotomy for myopia, it may be possible to reduce symptoms of presbyopia».

Vinciguerra et al proposed a 10 to 17 micron deep semilunar-shaped zone immediately below the pupillary center, steepening the corneal curvature in that area and reported promising results with this technique. Monovision is another extended technique usually in the form of dominant eye corrected for distance opposed to crossed monovision (dominant eye corrected for near) offering better near vision than control patients, with minimal compromise in stereo acuity and overall high patient satisfaction. Attempts for pseudo-accommodative cornea opened new concepts for correction of presbyopia; basically in the form of a peripheral near zone (concentric ring for near vision) offering better near vision than control patients, with minimal compromise in stereo acuity and overall high patient satisfaction. Vinciguerra et al proposed a 10 to 17 micron deep semilunar-shaped zone immediately below the pupillary center, steepening the corneal curvature in that area and reported promising results with this technique.

Monovision is another extended technique usually in the form of dominant eye corrected for distance opposed to crossed monovision (dominant eye corrected for near) offering better near vision than control patients, with minimal compromise in stereo acuity and overall high patient satisfaction. Attempts for pseudo-accommodative cornea opened new concepts for correction of presbyopia; basically in the form of a peripheral near zone (concentric ring for near vision) or in the form of a central near zone (central disc for near vision).

Charman concluded that the main requirement in presbyopia is extended binocular depth-of-focus to yield adequate distance and near vision with good retinal contrast at lower spatial frequencies, rather than the highest levels of acuity and modulation transfer function at a single distance. He further suggested that, for many presbyopes, this can be achieved by aiming residual high-order aberrations.

Artola et al found evidence for delayed presbyopia after photorefractive keratotomy for myopia due to the corneal aberrations induced, which may reduce the quality of the retinal image for distance but enhance near acuity by way of a multifocal effect that can delay the onset of age-related near vision symptoms. Dai was one of the first to propose the use of rigorous methodologies to theoretically optimize vision over the entire target range from near to distance.

Ortiz et al characterized the optical quality by the Strehl ratio, the spot size on the retina, and objective decimal visual acuity calculated based on measured corneal topography using Fresnel propagation algorithm based on a realistic eye model. They found that with a complete characterization of the eye and a complete propagation algorithm (that takes into account all refractive surfaces in the eye at the same time), it is possible to evaluate the optical quality in eyes of patients who have undergone central presbyLASIK treatment.

Reinstein et al successfully combined extended depth of focus with monovision in a micro-monovision protocol, whereas Epstein and Gurgos combined monocular peripheral presbyLASIK on the non-dominant eye with monofocal distance correction on the dominant eye.

Presbyopia and its refractive correction is one of the most frequently discussed topics in refractive surgery today. The purpose of this multicentric study is to investigate the objective and subjective visual results of a central multifocal presbyLASIK approach called PresbyMAX based on the creation of a biaspheric multifocal corneal surface with a multifocal central area of up to -2.25 D for near vision correction surrounded by an area where ablation is calculated for distance emmetropia. In this clinical trial we report the results obtained in a series of presbyopic hyperopic patients.

METHODS

Patient Selection

Inclusion criteria were medically suitable for LASIK, presbyopic with corrected distance visual acuity (CDVA) no worse than 20/25 in either eye, minimum follow-up of 6 months. Hyperopic patients with spherical equivalent refraction ≤+4 D in both eyes were included. Informed consent and permission to use their data for analysis and publication were obtained from each patient.

This study followed the tenets of the Declaration of Helsinki. All patients were dependent on reading glasses in daily life.

44 eyes of 22 patients undergoing bilateral LASIK for refractive presbyopic corrections were enrolled. The average age was 50±3 years (range, 44 years to 56 years). Patients included in the study had manifest spherical refractive error ranging from +1.50 D to +3.50 D with up to 1.00 D of astigmatism, with presbyopic adds of +2.25 D. Patients were enrolled in the study if they had best corrected distance visual acuity (CDVA) of 20/25 or better using the Early Treatment of Diabetic Retin-
opathy Study (ETDRS) chart, stable refraction for 1 year prior to the study and discontinued contact lenses for at least 2 to 4 weeks (depending on contact lens type) prior to the preoperative evaluation. Patients were required to have normal keratometry and topography.

Mean preoperative spherical equivalent was +2.34±0.41 D (range: +1.50 to +3.50 D, median +2.25 D). Mean preoperative astigmatism was 0.35±0.25 D (range: 0.00 to 0.75 D, median 0.50 D), and mean spectacle near addition was +1.86±0.24 D (range: +1.50 to +2.25 D, median +1.88 D).

Patients who suffered from systemic illness, had a calculated postoperative corneal bed thickness less than 300 μm after ablation, had preoperative central corneal thickness of less than 500 μm, had previous ocular surgery, or had abnormal corneal topography were excluded from the study.

Patients had to have pupil diameters smaller than 3.0 mm in photopic and larger than 4.5 mm in mesopic low condition to be included.

Additional exclusion criteria were clinically-relevant lens opacity, an ectopic pupil more than 1 mm off-centre and any signs of binocular vision anomalies at distance and near.

Table 1 shows descriptive statistics, including number of patients, gender, age, preoperative spherical equivalent refraction, preoperative cylinder and preoperative CDVA. Table 2 shows preoperative spherical equivalent refraction, intended postoperative spherical equivalent refraction, attempted spherical equivalent refraction. Figure 1 shows the distribution of age. The follow-up period was 6 months.
Preoperative assessment

A full ophthalmologic examination was performed on all patients prior to surgery including manifest refraction, cycloplegic refraction, slit-lamp microscopy of the anterior segment, dilated funduscopy, and Goldmann intraocular pressure measurement. The preoperative examination also included topography and keratometry (SIRIUS, CSO, Firenze, Italy), dynamic pupillometry (SIRIUS), corneal wavefront assessment (SIRIUS), and pachymetry (SIRIUS). Corrected distance visual acuity and uncorrected distance visual acuity (UDVA) were assessed with ETDRS Snellen charts. A line of acuity was deemed read only if at all five letters of that line were recognized correctly.

Surgical procedure

All treatments15,16 were prepared using the SCHWIND PresbyMAX treatment planning module in Aspheric mode17,18 (SCHWIND eye-tech-solutions GmbH and Co. KG, Kleinostheim, Germany). This module integrates bi-aspheric multifocal ablation profiles combining two focus-shifted aspheric profiles with different asphericities that compensate as well for the peripheral loss of energy due to an increased angle of incidence on the cornea19,20 and for biomechanical changes induced during LASIK. The treatment of ocular or corneal wavefront aberrations was not intended in this study.

In this presbyopic concept, both eyes equally contribute to providing visual acuity at all distances by actively participating in the visual process for creating binocular vision impressions. No differences between the dominant eye and the non-dominant eye are applied. The profile includes the aim of ~ –0.50 D myopic defocus for distance correction, equally for both eyes.

The sphere and cylinder values entered into the laser were based on the manifest refraction without nomogram adjustment, with both eyes attempting the same goal. Further, the flat and steep keratometry readings at 3 mm diameter as measured by the topographer were used for the compensation of the loss of ablation efficiency when the laser hits the cornea in non-normal incidence19. No nomogram was used to calculate the laser data entry. The CAM software platform was used to generate the ablation profiles (version 4.3).

Optical treatment zone diameters used for the hyperopic population were 6.3 mm (in 32%), 6.4 mm (in 36%), 6.5 mm (in 32%). For each treatment, the planning software calculated the size of the optimal transition zone, depending on the preoperative refraction and optical zone. The total ablation zone ranged from 6.5 mm to 9.0 mm.

Once finalized, the treatment plan was directly entered or transferred via Secure Digital memory card to the SCHWIND AMARIS excimer laser21.

The surgical procedure is exactly the same as for standard LASIK treatments with the AMARIS. All patients underwent LASIK using the AMARIS excimer laser operating with a superGaussian beam profile with active closed-loop energy stabilization. The beam size is 0.54 mm at full-width-at-half-maximum with a pulse-rate frequency of 500 Hz. The AMARIS possesses an active infra red pupil tracking system with a sample rate of 1050 Hz which results in a total physical delay time of 2.6 milliseconds and includes limbus, rolling and torsion tracking.

Both the flap and the ablation profile were centered on the corneal vertex for all patients, which closely approximates the visual axis. The corneal vertex was determined at the topographer. Centration on the corneal vertex was used so that the spherical aberration induction was symmetrical around the visual axis rather than the line of sight. If an ablation is performed on the line of sight in an eye with a large angle kappa, the patient will suffer from a significant amount of coma which may be detrimental to their vision rather than the expected increase in depth of field from spherical aberration induced symmetrically about the corneal vertex.

Postoperative evaluation

Patients were reviewed at one day, one month, three months, and six months. All postoperative follow-up visits included measurement of monocular and binocular UDVA at both distance and near. Near acuity was assessed with the Spanish version of the Radner Reading Charts at 40 cm. All tests were performed monocularly and binocularly. Manifest refraction and CDVA were obtained at all postoperative visits after the one day appointment. SIRIUS topography and corneal aberrometry were performed at the three and six month visits.

Outcome measures

Efficacy

Binocular UDVA, binocular UNVA were assessed.

Safety

Loss and gain in lines of CDVA and CNVA have been monocularly and binocularly evaluated.

Accuracy

Scattergram for spherical equivalent refraction at 6-month follow-up has been plotted. The refractive deviation from target for distance correction has been evaluated in spherical equivalent and astigmatism.
RESULTS

Preoperative

Binocular UDVA ranged from +0.3 LogMAR to +0.7 LogMAR (20/40 to 20/100), whereas binocular CDVA was 0.0 LogMAR (20/20) in all patients. Binocular DCNVA ranged from +0.3 LogRAD to +0.5 LogRAD (J4 to J7), whereas binocular UNVA ranged from +0.5 LogRAD to +0.9 LogRAD (J7 to J12), and binocular CNVA ranged was 0.0 LogRAD (J1) for all patients.

Efficacy

UDVA ranged from 0.0 LogMAR to +0.5 LogMAR monocularly (20/20 to 20/63), and from 0.0 LogMAR to +0.3 LogMAR binocularly (20/20 to 20/40), whereas CDVA ranged from 0.0 LogMAR to +0.3 LogMAR monocularly (20/20 to 20/40), and from 0.0 LogMAR to +0.2 LogMAR binocularly (20/20 to 20/32). The loss in monocular CDVA was statistically significant (p<.0001). DCNVA ranged from 0.0 LogRAD to +0.3 LogRAD monocularly (>J1 to J4), and from 0.0 LogRAD to +0.2 LogRAD binocularly (>J1 to J3), whereas UNVA ranged from 0.0 LogRAD to +0.3 LogRAD monocularly (>J1 to J4), and from 0.0 LogRAD to +0.2 LogRAD binocularly (>J1 to J3). The improvement in monocular DCNVA was statistically significant (p<.0001).

Monocular distance vision was good, with 89% eyes achieving 20/32 or better. The binocular distance vision was 20/25 or better in 80% of the patients (Fig. 2).

Table 3 presents the mean logMAR UDVA. The improvement of binocular UDVA compared to the monocular UDVA of the distance eyes was statistically significant (p<0.01).

Near vision was at least J3 (better than newsprint) for 91% of the eyes monocularly, whereas 91% of the

| Table 3: UVA parameters |
|-------------------------|------------------|
|                        | Preoperative     | Postoperative   |
| Monocular UDVA (logMAR)| 0.65±0.13        | 0.15±0.10       |
|                        | 0.4 to 0.8       | 0.0 to 0.5      |
| Binocular UDVA (logMAR)| 0.50±0.13        | 0.09±0.08       |
|                        | 0.3 to 0.7       | 0.0 to 0.3      |
| Binocular UDVA summation| 1.345±0.136      | 1.058±0.064     |
|                        | 1.17 to 1.60     | 1.00 to 1.14    |
| Monocular UNVA (logRAD)| 0.82±0.11        | 0.16±0.09       |
|                        | 0.6 to 1.1       | 0.0 to 0.3      |
| Binocular UNVA (logRAD)| 0.71±0.10        | 0.08±0.07       |
|                        | 0.5 to 0.9       | 0.0 to 0.2      |
| Binocular UNVA summation| 1.258±0.121      | 1.099±0.130     |
|                        | 1.00 to 1.55     | 1.00 to 1.28    |

Fig. 2.
patients binocularly were able to read J2 (very small print) (Fig. 3).

For combined distance and near vision, 20/25 and J2 was achieved in 70% of the patients, whereas 20/32 and J3 was achieved in 95% of the patients (Fig. 4).

**Safety**

11% eyes lost two or more lines lines of monocular CDVA, whereas 5% patients lost two or more lines lines of binocular CDVA (Fig. 5).
Accuracy

Figure 6 shows a histogram of the accuracy of the spherical equivalent correction. Figure 7 shows the accuracy in terms of astigmatism. Scattergram of the achieved versus attempted refractive corrections show only –7% undercorrection at SEq. The global refractive deviation from target refraction was –0.1±0.3 D for
SEQ, $0.1\pm 0.1$ D for Ast, and $0.1\pm 0.3$ D for the norm of the U-Vector. 95% of the eyes were within 0.50 D of target refraction, with 100% within $\pm 1.0$ D of spherical equivalent.

6 months postoperatively, the mean spherical equivalent for distance refraction was $-0.08\pm 0.34$ D (range: $-1.00$ to $+0.50$ D, median 0.00). The postoperative astigmatism was $0.12\pm 0.14$ D (range: 0.00 to 0.50 D, median 0.00 D).

**DISCUSSION**

PresbyMAX was a well tolerated, safe and effective procedure for the treatment of presbyopia in hyperopia up to $+4$ D.

After PresbyMAX treatment, the distance vision was found to be fairly good, with a mean UDVA of 20/28 monocularly and 20/24 binocularly.

All patients could read newsprint (J3) and 91% could read J2. The mean age was 50 years.

The main goal of a surgical procedure to correct presbyopia is to enhance not only distance but also near visual acuity and the range of relatively clear vision. The surgical techniques to correct presbyopia can be broadly categorized as follows: systems that mimic the crystalline lens and bi- or multifocal techniques that enhance depth of focus and monovision. The use of artificial aperture stops has been also established for increasing depth of focus. Patients may rate an intervention highly even though essential features of normal visual perception are degraded. For example, monovision is highly rated by patients even though binocular vision is compromised. Measuring the depth of focus is a useful marker but measuring acuity at typical near vision distances may be closer related to patients’ real expectations and concerns.

Monovision LASIK has been found to produce high levels of patient satisfaction, with Goldberg reporting 96% satisfaction and Miranda 92%.

Contact lens monovision and LASIK-induced monovision traditionally use a nomogram for near addition, with the degree of anisometropia increasing from approximately $-1.50$ D for a 45-year-old patient up to $-2.50$ D for a 65-year-old patient. Tolerance for monovision reduces with the value of induced anisometropia and is no longer tolerated when it is larger than $2.50$ D.

The performance of different types of IOLs (refractive, diffractive, pseudo-accommodating, and multifocal) is constantly being improved, but the IOLs cause a decrease in near vision contrast sensitivity.

PresbyLASIK treatment uses the principles of LASIK surgery to create a multifocal corneal surface aimed at reducing near vision spectacle dependence in presbyopic patients. This treatment constitutes the next step in the correction of presbyopia after monovision LASIK. The term presbyLASIK indicates a corneal surgical procedure based on traditional LASIK to create a
multifocal surface able to correct any visual defect for distance while simultaneously reducing the near spectacle dependency in presbyopic patients.\textsuperscript{32,33} Using a micro-monovision protocol, Reinstein et al.\textsuperscript{12} recently succeeded with an intended postoperative refraction of plano to low myopia for the dominant eye and in the range of −1.00 to −1.50 D for the non-dominant eye, irrespective of the patient’s age, and determined that the near eye had a beneficial effect on binocular distance UCVA when compared to the monocular distance UCVA of the dominant (distance) eye.

Pinelli et al.\textsuperscript{34} investigated the outcome of the correction of presbyopic patients with hyperopia using a peripheral presbyLASIK algorithm called Peripheral Multifocal LASIK (PML). This treatment creates a multifocal corneal profile in a 6.5 mm diameter zone by the combination of a positive ablation performed over a 6.5 mm zone and a negative ablation performed over an optical zone no smaller than 5 mm. The hypothesis is that the ring between the 5 and 6.5 mm optical zones provides multifocality.

In several reports\textsuperscript{7,23,35,36}, Alió et al. demonstrated the efficiency, predictability, stability, safety, and visual quality of central presbyLASIK in presbyopic patients with hyperopia.

In another study\textsuperscript{11}, they reported the correlation of the clinical results of this presbyLASIK method with a theoretical predictive model, showing the adjustment of both.

Concerning pseudo-accommodation and multifocality, these methods can neither correct presbyopia, nor restore accommodation, nor stop the progress of presbyopia, nor slow down the progress of presbyopia. If the lens cannot accommodate, after any pseudo-accommodativo or multifocal approach, the lens will still not accommodate. Using presbyLASIK techniques it is possible to benefit from pseudo-accommodation and multifocality, reducing dependency on reading-spectacles by providing controlled extended depth-of-focus. Treatments can be prescribed for preventing latent presbyopic symptoms, delaying reading-spectacles demands while presbyopia progresses and treatments may be repeated with minimum risk if reading-spectacles demands renew.

If no cataracts are present, but refractive defects exist; presbyLASIK techniques offer the potential to correct far-distance refraction and to alleviate the presbyopic symptoms, with the goal of spectacle-free vision at all distances.

The specific planning software platform allows using WaveFront diagnostic data together with Presbyopic compensation combining the advantages of both techniques (improved visual outcome through WaveFront guided correction\textsuperscript{37,38} and enhanced pseudo-accommodation). Finally, a Controlled Multifocal Vision is expected and the profile meets the requirements:

- Multifocally, the centre is corrected for near and the periphery for far vision.
- Optimised bi-aspheric profile.
- Adding a pre-calculated amount of different high order spherical aberrations.

In our cohort, patients have got (both objectively and subjectively) good distance vision, very good vision at the intermediate region, and excellent near vision. Combined, it offers a possible compromise for the whole distance range.

There was a wide range for the postoperative DC-NVA (0.2±0.1 LogRAD (−J2.5), 0.0 LogRAD to +0.3 LogRAD monocularly (>J1 to J4), and 0.1±0.1 LogRAD (−J1.2), 0.0 LogRAD to +0.2 LogRAD binocularly (−J1 to J3)), whereas the outcome for near was excellent (0.2±0.2 LogRAD (−J2.3), 0.0 LogRAD to +0.3 LogRAD monocularly (>J1 to J4), and 0.1±0.1 LogRAD (−J1.2), 0.0 LogRAD to +0.2 LogRAD binocularly (>J1 to J3)). This apparent contradiction can be explained at the light of the slightly myopic spherical equivalent postoperative (−0.1±0.3 D, −1.00 D to +0.50 D) further improving UNVA at the cost of slightly diminishing UDVA (0.2±0.1 LogMAR (−20/28), 0.0 LogMAR to +0.5 LogMAR monocularly (20/20 to 20/63), and 0.1±0.1 LogMAR (−20/24), 0.0 LogMAR to +0.3 LogMAR binocularly (20/20 to 20/40)).

Nonetheless, it is really important to individually check whether a patient is a PresbyMAX candidate or not. The patients shall be asked for their profession, hobbies, and expectations comparing whether the postoperative visual performance provided with the ablation profile can comply with patient’s needs. A trial with adequate multifocal contact lenses or just providing slightly defocused images (via trial frame) to the retina simulate postoperative visual impressions in a way and verifies for patient’s acceptance.

The aim of this approach is a spectacle-free vision in usual day-life-situations but with possibly need of additives, i.e. spectacles for reading or distance, in case of special demands while focussing. Well-lit conditions provide best near performance, dimmed conditions are optimal for distance-patients profit wearing sunglasses for distance. Centring on corneal vertex is essential and helps to reduce the induction of unwanted high-order aberrations, especially disturbing asymmetrical aberrations like coma.

Controversy remains regarding where to centre corneal refractive procedures to maximize the visual outcomes. A misplaced refractive ablation might result in undercorrection and other undesirable side effects. The coaxial light reflex seems to lie nearer to the corneal intercept of the visual axis than the pupil centre (PC) and is, thus, recommended that the corneal coaxial light reflex be centered during refractive surgery. Boxer Wachler et al.\textsuperscript{39} identified the coaxial light reflex and used it as the centre of the ablation. De Ortueta and
Arba Mosquera\textsuperscript{40} used the corneal vertex (CV) measured by videokeratoscopy as the morphologic reference to centre corneal refractive procedures.

The centre of the pupil considered for a patient who fixates properly is the locus where the line-of-sight passes through, which is the reference axis recommended by the OSA for representing the wavefront aberration\textsuperscript{41}.

Nevertheless, because the pupil centre is unstable, a morphologic reference is more advisable\textsuperscript{42,43}. It is well known that the pupil centre shifts with changes in the pupil size, moreover, because the entrance pupil we see is a virtual image of the real one.

Due to the smaller angle kappa associated with myopes compared with hyperopes\textsuperscript{44,45}, centration issues are less apparent.

Nowadays, technology has evolved significantly and uses sophisticated algorithms, optimized tools in the planning, and proposes the challenge of improving surgery outcomes in terms of visual acuity and night vision. At the same time, patients have a better understanding and are better informed with regard to the potential of laser refractive surgery, raising quality requirements demanded to clinical staff and equipment.

In discussing visual benefit, although VA data are helpful, there may be patients with 20/20 vision who are unhappy with their visual outcomes due to poor mesopic and low-contrast VA.

Human vision is a binocular process. Having two eyes gives binocular summation in which the ability to detect faint objects is enhanced. It can give stereopsis in which parallax provided by the two eyes’ different positions on the head give precise depth perception. Such binocular vision is usually accompanied by binocular fusion, in which a single image is seen despite each eye is having its own image of any object.

Literature suggests that marked anisometropia is uncommon\textsuperscript{66,47} either in the magnitude of sphere or astigmatism, with few notable exceptions concluding that the axis of astigmatism does not follow any particular rule (mirror or direct symmetry) across right and left eyes.

Porter et al.\textsuperscript{46} confirmed in a large population that although the pattern of aberrations varies from subject to subject, aberrations, including irregular ones, are correlated in left and right eyes of the same subject, indicating that they are not random defects.

Wang et al.\textsuperscript{47} found that anterior corneal wave aberrations varied greatly among subjects, but a moderate to high degree of mirror symmetry existed between right and left eyes.

Our analysis suggests that bi-aspheric multifocal central presbyLASIK treatments for hyperopia with or without astigmatism presents fair but sufficient simultaneous vision (distance and near) 6-month after surgery.

All patients are completely spectacle-free in daily life. Causatively, we have to remember the age of our patients which was 50±3 years, so apparently some physiological accommodation is still available as a reason for improved near visual acuity. Also, a slight over-correction towards myopia, which is seen in some cases, should be responsible for improved near performance apart from central steepening. Nonetheless, a longer follow-up should be considered for a final statement.

Far vision is affected by the presence of the central hyperpositive area when pupil miosis occurs. The loss of lines for the CDVA in some patients may be correlated to the light distribution concept of the PresbyMAX software which leads to a division of the light for near of 35 to 40%, intermediate 15% and far distance of 45 to 50%. The PresbyMAX concept is definitely pupil dependent so that a further effect could be a pupil size which is closer to photopic light condition (e.g. ~40 lux) during the measurement process of CDVA rather than to mesopic low (e.g. ~0.4 lux). The time of adaptation to the multifocal cornea that was induced might play a role in individuals, too.

In comparison to other surgical presbyopic treatments like the refractive lens exchange with MIOL, corneal multifocal surgery has the major advantage of being a less invasive technique with decreased risk of severe complications and with the possibility of additional correction of higher order aberrations.

The PresbyMAX method uses bi-aspheric multifocal ablation profiles which can be combined with the correction of low or moderate ametropia. Experience in higher dioptries (more than 4 dioptries) is not given at this stage because it was not part of our study design. A target myopia of −0.50 D for far distance is combined with the induction of central steepening associated with increased pseudoaccommodation. Thus, two factors that help to improve near vision performance. Reflecting our experience and 6 month outcomes, PresbyMAX seems to be an efficient, safe and stable technique. Nonetheless, the adaptation to the new visual impression takes a while. Near performance was very good from day one after surgery, but the distance vision improved slowly. Patients were usually satisfied with distance vision at the 3 month check-up, but satisfaction levels improved even further at 6 months.

**CONCLUSIONS**

In our cohort, at 6 months, 80% of patients achieved UDVA 0.1 logMAR or better, 91% patients obtained UNVA 0.1 logRAD or better, and 96% of eyes were within 0.75 dioptries (D) of defocus. Postoperative mean spherical equivalent refraction was −0.08±0.34 D. 95% of patients achieved UDVA 0.2 logMAR or better AND UNVA 0.2 logRAD or better. No significant differences between males and females were found.
Patient selection and expectation management is essential to achieve patient satisfaction. Even though optically the results are predictable and good, some patients find it difficult to adapt to the compromise, others are dissatisfied by the minor loss of distance VA. Certain individuals are best suited for PresbyMAX. A trials with multifocal contact lenses or trial frames that creates slightly defocused images to the retina can be used to simulate postoperative visual impressions and verify patient acceptance. Asking patients about their profession, hobbies, and expectations helps to understand whether the postoperative visual performance can meet their individual needs.

In conclusion, we found the PresbyMAX protocol using the AMARIS and CAM was a well tolerated, highly effective and safe procedure for treating patients with presbyopia in moderate hyperopia.

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